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ABSTRACT

The paper argues that a relationship between visualization and mathematical problem solving ability exists. Research suggests that visual imagery leads to increased understanding of mathematical concepts at both the primary and secondary levels. Mathematical potential is not necessarily "born." Potential can be created in the least likely students if teachers accept that art has its place in the craft of mathematics. A multi-modal approach to instruction is both a logical and viable alternative to the established methods that have limited students and teachers alike. An integrated approach to teaching mathematics that includes pictorial journal writing or note taking generates an opening for creative expression. The teaching of mathematics offers many opportunities for imaginative and original style with equally distinct and productive results. (Contains 23 references.) (MM)

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THE LINK BETWEEN ART AND MATHEMATICS

BY

ANDI STIX

1994

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THE LINK BETWEEN ART AND MATHEMATICS

There would seem to be an implausible relationship between art and mathematics. After all, the two domains seem to depend on vastly different thinking patterns. We do not question the interrelationship between science and mathematics, and scientific process is clearly contingent on mathematics. How then did Ferguson (1977) manage to put together a historical review linking art and technology? Ferguson's research indicates that inventors and art are more closely affiliated than either group would have us believe.

Ferguson cites many examples of how inventors have depended on art. In 1588, as a way of bringing to the public's notice that all mechanical arts depend on mathematics, Ramelli gave over eight large folio pages in the preface of his machine book to this questionable notion. Benjamin Henry Latrobe, a distinguished architect and engineer, was an accomplished watercolorist. Samuel Morse, inventor of the Morse Code and the telegraph, as well as Robert Fulton, inventor of the steamboat frame, were both artists before they converted to careers in technology. Ferguson's testimony of artists-turned-technologists and vice-versa is extensive and persuasive. The relationship between technology and art truly does exist. Indeed, the relationship also justifies the necessity for understanding how visualization can elucidate the mystery of mathematics for the typical "mathematic phobic."

As we examine the relationship between spatial visualization and journal writing in mathematics, it becomes apparent that the use of pictorial journal writing in expressing the understanding of mathematical concepts has much to offer educators and students alike.

Mathematics as a Creative Art

Creativity and language arts have shared a thriving partnership in the classroom to the benefit of both students and teachers. Students always seem to

appreciate an occasion to write to music or to create a poem in response to an intriguing photograph. The outcome of these efforts is both favorable and rewarding. These divergent learning processes clearly elevate student curiosity and performance. Language arts has commonly been the area of an instructional approach to expression that depends on the use of all techniques of communication (Baum, 1990; Galyean, 1981; Good and Brophy, 1987). Why then has the advancement of such assorted learning processes been overlooked in the teaching of mathematics?

Teachers today are faced not only with oversized classes, but with students of differing abilities, varying in the ways they process information. We also know that teaching to a group of twenty-eight students individually is not only unrealistic, but futile. What is feasible, however, is modifying instruction to reach a larger percentage of students. Language arts techniques can expedite the proficiency with which this goal is achieved.

When we use the differences among our students to cultivate instructional strategies, we can help them to receive information with increased self-confidence Students need to be persuaded to feel assured that they have the skill to communicate their ideas to themselves, to their peers, and to their teachers. Often the study of mathematics does not provide sufficient opportunity for students to express themselves with assurance. The opportunity for choice in the teaching mathematics can certainly alter this legacy. Pictures, music, and meter have guided students' expressive writing with striking results. Such imaginative techniques diverge from the conventional and are met with eagerness by students. Such avid interest is not always a typical response when mathematics is the subject being taught. We must ask ourselves how we can convey the zeal that accompanies creativity to the teaching of mathematics?

Once we recognize that in addition to different learning processes students also have varying abilities to integrate

verbal, spatial, and numerical information, then we can reach a greater audience in the field of mathematics. Not only must we recognize students' abilities to be receptive and to integrate information, but we must acknowledge their abilities to communicate a conceptual understanding of the newly presented material. Journal writing has historically been the domain of language arts. The process has persisted because it grants students a chance to express themselves minus the restrictions of the usual approaches for written expression. Journal writing is also a inestimable vehicle for teachers since it encourages opportunities to view students' comprehension of material. When journal writing is used in mathematics it stimulates the graphic expression of thought and the utilization of a spatial mode of communication. Students keep linguistic, numeric, and pictorial records of what they have learned in either portfolios or diaries. In so doing, they are following a heritage of distinguished individuals whose diaries have much to teach us about the association between art and mathematics.

Testimonies of Experts

As educators, we have much to learn from the testimonies of historically notable individuals. In 1888 the founder of the science eugenics, Francis Galton, stated that he thought in images (Galton, 1907). Albert Einstein claimed that his ability to think visually was so strong it was actually arduous for him to translate his thinking into traditional language (Holton, 1972). William James considered the role that visual or tactile imagery might play in human cognition (Wilshire, 1971) and involved his colleagues in a dialogue over whether thought was possible without language. Galton gave an account of Sir Flinder Petrie, Egyptologist, who used a slide rule in his mind to calculate addition. He used his "mind's eye" to read off the sum (Galton, 1907) after he placed one ruler against the other.

How can we use these records to teach mathematics with a superior

understanding of the assorted approaches we have yet to employ on a widespread scale? Arnheim (1969) asserted that internal speech is not the only example of thought process that exists. Visual imagery is just one variety of cognitive operation that survives without language. Arnheim opened the way for many other theorists to confirm the need for confronting the teaching of mathematics with an improved understanding of ready possibilities.

Visualizing Mathematics

The battle to find provisional ways to amplify a student's ability to conceptualize new information in mathematics continues to present a challenge. Presmeg (1989) theorizes that information will be more purposeful if it is presented within the student's frame of reference. Once that is instituted, visual imagery is more likely to lead to increased understanding of mathematical concepts at both the primary and secondary levels.

Many researchers agree that there is a strong relationship between visualization and mathematical problem solving ability. Visualization often provides students with additional strategies to solve the problems so they have more to draw upon within their repertoire (Ben-Chaim, Lappan, and Houang, 1989).

Journal Writing in Mathematics

Expressive vs. Receptive Tasks

When children seem to comprehend mathematical ideas that have been conveyed to them, they are showing confirmation of receptive ability. A genuine mathematical task that probes a student's ability to remember an addition fact with rational numbers is an example of one way to ascertain how well information is being acquired.

Conversely, when a student is compelled to express this understanding in a more elaborate procedure, such as adding rational numbers whose sum is greater than one, there is often difficulty in communicating the concept. While children often seem to grasp the mathematical ideas presented to them, they often cannot convey these ideas to others or even to themselves (Clements and Del Campo, 1989).

Therefore, it is crucial that teachers persuade students to write expressively. Not only will students then have the occasion to initiate communication with themselves, but their teachers will acknowledge that students have something valuable to say about how and what they are learning (Graves, 1978).

The Search and the Findings

The most constructive method of using writing to sustain students in their schooling of mathematics is through journal writing (Vacca and Vacca, 1986). Individualized learning and discovery is a significant attribute ascribed to the journal writing process.

In their studies of journal writing, Selfe, Petersen, and Nahrgang (1986) determined that the entries revealed a catalytic process in which the expository writing of thoughts ignited the act of discovery. They noticed that while the beginning section of entry forms regularly lacked focus, an awareness of how to approach the solution began to surface as students had the chance to explore their thoughts and to make them more concrete.

An Intimate Relationship With Information

A group lesson becomes a more intimate experience when students have an opportunity to write. It also bridges the import of group work and individualized instruction. Journal writing

gives students the opportunity to translate and connect their personal experiences to

the lesson while encouraging them to explore and discover (BeMiller, 1987).

Journal writing permits the students to classify, construct, and create meaning of concepts for themselves in a logical path. Initially, students organize the information for themselves; then later they are able to communicate these ideas to others (Smith, 1982). Journal writing furnishes students with the opening they need to become active participants in their own learning.

Assessing the Student

Educators know that one of the greatest barriers to assisting a student is understanding the problem. As educators, we know it is often almost impossible to judge what is creating confusion for a student. It would help if we could procure a picture of exactly what is happening as each student strives to critically organize the information we are feeding him. If we could do that, we could find the barrier to his understanding and help to facilitate his success.

Misunderstandings may not display themselves in an average homework assignment or in a plain numerical examination. We know that because students can trust in a purely memorized process for calculating equations, misconceptions often do not become obvious (Davison and Pearces, 1988).

Journal writing permits students to declare their understanding of what they have learned and, equally important, grants teachers a chance to see where there is a potential for confusion.

Evans (1984) responded to using journal writing in the classroom by asserting, "I could immediately see who understood the concepts I was teaching and, more importantly, who didn't" (834). In addition, Burton (1985) said that when a student is encouraged to write, the misinterpretations are clarified. In this way, the student is able to be remarkably precise about the origins of the problem.

Retention

Evans (1984) observed that after information was discussed in a journal entry, students' ability to remember and retain information was improved. Because students had personal ownership of the information, the inclination to recall standard text definitions became easier. Evans' class of fourth grade journal writing students performed better than a control group on a unit of multiplication even though the control group had high CTBS scores at the beginning of the year.

Tierney (1986) feels strongly that students become "owners" rather than "renters" of information. In his study, fifth grade students who utilized writing as a tool for personalizing information had a higher retention rate than did the control group. Schubert (1987) tested children's facility to remember information a year later. On the post-test for the fraction chapter in grade five, children who formerly used the journal format had a range of 71 percent to 100 percent, with an average of 94 percent. Students who did not employ the journals had a range of 35 percent to 100 percent, with an average score of 81 percent. While there will always be students who grasp mathematics easily and can score 100 percent, the lower scores of 35 and 71 respectively show the relevance of the use of journal writing.

Pictorial Journal Writing

The most intricate inventions frequently begin with a nonchalantly drawn sketch. Non-verbal thought has molded much that is creative and original in the world. Often, nothing more than a sudden perception of a visual image that flashed through the mind is needed to devise something that is concrete and retains its inexplicable properties. Ferguson's (1977) research confirms the early utilization of pictures in manuscripts, or diaries. What he exposes facilitates our understanding of how pictorial journal writing can be the solution we need to release mathematical aptitude.

History

Pictorial journal writing is not a recent phenomenon. There is evidence of this format as early as the sixteenth century. Ferguson (1977) scrutinized several areas to prove how integral the influence of drawing has been to the development of mankind. Technology, graphic design, art, and perspective are among the areas where creative pictorial representations have surfaced. Ferguson's research advocates the philosophy inherent in pictorial journal writing and champions the need to cultivate potential talents as a means for developing mathematical skill.

Technology

Through the courtesy of Ferguson's survey, we have the opportunity to visit the middle of the fifteenth century. This gives us the chance to observe Leonardo da Vinci as he completes one of his many technical drawings in the pages of his personal notebook. Thousands of pages of such drawings have been left to us. In Leonardo da Vinci's age, technical notebooks of this kind were routinely circulated among engineers. Engineers typically drew illustrations of their visual images. Ferguson surveyed many historical notebooks that verify the pictorial form of exchange among technologists.

Book Seven of Francesco di Giorgio Marini's "Trattato di Architettura," drafted around 1475 (Ferguson, 1977, 828), was one of the most influential books of its time. This book is a striking example of how technical information can be relayed through illustrations. Nonetheless, it is the accompanying text that is indisputably unique. When they are separate from the illustrations, the words are meaningless. Although notebooks regularly contained nothing except pictures, Marini's notebook virtually proclaims that language does, in fact, strengthen the expression of the illustration.

Graphic Drawing

Graphic drawings or illustrations have routinely been used to elucidate pictorial representations. Many techniques, such as perspective drawing, exploded view, orthographic projection, isometric view, or the ordinary graph of a curve, have inaugurated the extensive ways in which artists, mathematicians, and inventors communicate their innovations. In fact, a persistent theme in the literature is the relevance of pictorial perspective in easing the ability to communicate. When the visual image in one mind can be shared, then the facility for peers to trade ideas is strengthened.

Present Findings

When students are encouraged to express themselves in the field of mathematics, we have the opportunity to observe their willingness to investigate areas that have been untouched.

Clements and Del Campo (1989) urge that students should "be free to express themselves...by speaking, writing, drawing, performing, and imagining mathematics" (p.27). As we cultivate this freedom in students and invite them to utilize many modes of expression in journal writing, we stimulate awareness of individual strengths and weaknesses (Baum, 1990). Analogously, BeMiller (1989) recommends that as students interact with different modes of expressions, they "consequently visualize more relationships and [they have] better exposition of these ideas" (365).

It is unfortunate that systems of multi-modal writing appear to deteriorate on after the third grade. Teachers find it exacting to sanction an approach that feels untraditional and might be regarded as a "game." However, age appropriateness is not an issue when the "game" fosters understanding and growth. Any suspicions we might have about the constructiveness of games in the classroom disappear when we

evaluate the results.

Nonetheless, research supports the fact that concrete, semi-concrete, and pictorial writing are just as important in the middle and upper grades as in lower, primary grades. Ben-Chaim, et al., (1989) advocate that adolescent students build with cubes, represent three dimensional objects in two dimensional drawings, and read from each other's drawings. Most students will have difficulties visualizing hidden parts or realizing the correct elements of dimensionality unless they are exposed to multi-modal instruction and pictorial drawing.

Current researchers share a sense of responsibility to the relevance of including pictorial representations as an element of journal writing. Dirkes (1991) is even more precise about how pictures should be used when students write. She recommends that students be encouraged to refer to their own drawings as a source of information. Moreover, she recommends that numbers be placed as close as possible to the illustration they represent.

Dirkes also advocates the use of reading and drawing assignments. She gives an general structure for solving a mathematical problem. For instance, students are urged to read the example more than once. Next, the student is expected to draw something to illustrate the facts. Finally, the pupil is required to list additional ideas.

I compared (1992) the effects of using pictures with two groups of students from a required mathematics methods course for teaching at the elementary level. The control group, designated as bimodal, was only allowed to use words and numbers in their assignments. The experimental group, designated as trimodal, was allowed to use words, numbers, and pictures in their journal writing assignment.

Between the two groups, the following areas were significant: The trimodal group reported a greater sense of task and a more focused introduction than the bimodal group. The trimodal group pointed to a number of reasons for their superior response. They felt that the pictures helped define ideas, presented better evidence to

confirm their points, aided in determining a logical order, and cultivated their ability to express themselves more succinctly. Both groups agreed that their math anxiety decreased and their self-confidence increased as a consequence of the journal assignments.

When activities include drawings it helps augment the time spent during the thinking process. And when information is retained it reflects a grasp of the presented material. Two goals of teaching are understanding and retention. When instructors teach for understanding, they also teach for retention (Phillips, 1987). The impact of visual spatial skills on achievement merits restating. It is only logical that feelings of self-confidence and success will be enhanced when students begin to show an increase in their achievement scores. One study with low achieving students demonstrates that exercises used in visual spatial activities not only improved their understanding of the material, but greatly increased their self-concept (Lord, 1987). My own conclusion supports increased self-confidence when math problems are approached and solved in conjunction with pictures in journal writing.

Conclusion

Mathematical potential is not necessarily "born." We can "create" potential in the least likely students if we accept that art has its place in the "craft" of mathematics. There as many ways to teach mathematics as there are to paint the same scene. To the artist, as to the student, it is always a matter of how the "subject" is perceived. For student and artist alike, it is always a matter of how information--whether it is verbal or visual--is integrated. The approaches are as diverse as the avenues students are willing to take for expressing their ideas if they are given the opportunity.

As educators and parents, we need to view strengths and weaknesses as tools that can be effectively used to help students communicate these ideas. When we

recognize that different learning styles represent assets as valuable as individual artistic expression, then we can help students to convey their needs and teach for understanding and retention.

A multi-modal approach to instruction is both a logical and viable alternative to the established methods that have limited students and teachers alike. An integrated approach to teaching mathematics that includes pictorial journal writing or note taking generates an opening for creative expression. The teaching of mathematics offers many opportunities for imaginative and original style with equally distinct and productive results.

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